ELECTRICAL IMPEDANCE TOMOGRAPHY FOR SUBSURFACE IMAGING

TECHNOLOGY DESCRIPTION

Electrical Impedance Tomography (EIT) For Subsurface Imaging is a technique for reconstructing subsurface electrical impedance. The result of reconstruction is a two- or three-dimensional map of the underground electrical impedance distribution made from a series of voltage and current measurements. The EIT For Subsurface Imaging approach uses buried electrodes to measure changes in electrical impedance. The measurement data are collected by an automatic data collection and switching system. A modular multiplexer operating at a switching speed of 100 milliseconds centrally controls the switching system. The switches are rated at 10 amperes and 500 volts. The multiplexer control allows for complete freedom in specifying which electrodes are used for the current source and which are used for the potential measurement. This protocol is specified by the user in an ASCII file that is read by the control program. The control software is written in a graphical interface language that is user friendly. EIT For Subsurface Imaging has been used to map subsurface liquids during natural or man-induced processes, and to map geologic structures. This technology is primarily being developed to map the spacial extent of Dense Non-Aqueous Phase Liquids (DNAPLs) without benefit of baseline data; the usual circumstance, where access to the contaminated soil is possible only after the fact.

The baseline technology is the analysis of underground samples and geophysical data obtained using conventional drilling, Geoprobe™ holes, or cone penetrometer techniques. The approach used for measuring underground conditions with the baseline technology is the systematic penetration of the subsurface with boreholes and/or hydraulic push holes in a grid or circular pattern to permit the use of conventional measuring instruments, such as geophysical logging tools, and the employment of underground sampling techniques. The samples collected are usually sent to an off-site laboratory for analysis. Data from the laboratory analyses generally takes one week to several weeks to receive. Moreover, the time delays resulting from off-site analysis can result in significant downtime costs when the results of those analyses are essential to guiding characterization and remediation operations.

TECHNOLOGY NEED

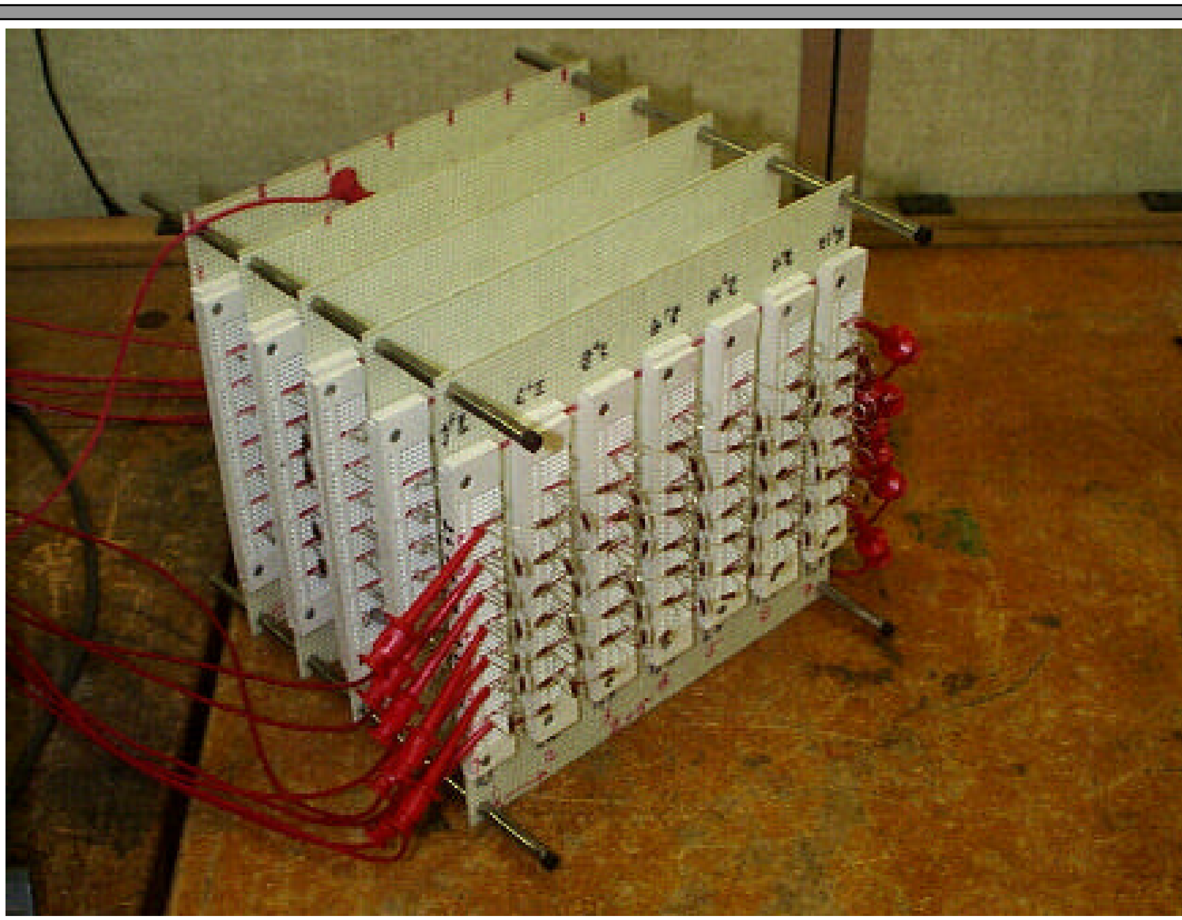
Residual industrial solvents, primarily DNAPLs, are currently the most significant challenge for the successful completion of many large groundwater and soil cleanup efforts at U.S. Department of Energy and commercial sites. Slowly dissolving DNAPLs provide a major source of present and future groundwater contamination. Adding to the challenge is the fact that DNAPLs are very difficult to characterize in the subsurface–especially when they are found in dispersed blobs as is typical at many sites. At sites where subsurface DNAPLs are suspected, real-time characterization of the nature and extent of the contamination is important to a cost-effective remediation strategy. Traditional sampling approaches generally are not successful at locating DNAPLs. Above the water table, residual DNAPLs will reside in intergranular pores held by capillary forces. Below the water table, DNAPLs behave in a complex fashion, moving downward as an immiscible phase and accumulating in highly concentrated discrete and dispersed ganglia. Because of the physical and chemical characteristics of DNAPLs, characterization and remediation methods that minimize unnecessary waste generation are prudent. Finally, precise delineation of DNAPL areas will facilitate the design of appropriate remediation strategies and help keep cleanup costs from escalating. This work addresses Site Technology Coordination Group (STCG) Need Numbers:

- OK99-01 - Characterization and Removal of Dense Non-Aqueous Phase Liquids (DNAPLs) and Light Non-Aqueous Phase Liquids (LNAPLs) from Soil and Groundwater
- RL-SS25-S - Chemical Form and Mobility of Dense, Non-Aqueous Phase Liquids (DNAPLs) in Hanford Subsurface Transport of Contaminants
- ORHY-01a - Dense Non-Aqueous Phase Liquids (DNAPLs) Source Characterization, Containment, and Treatment

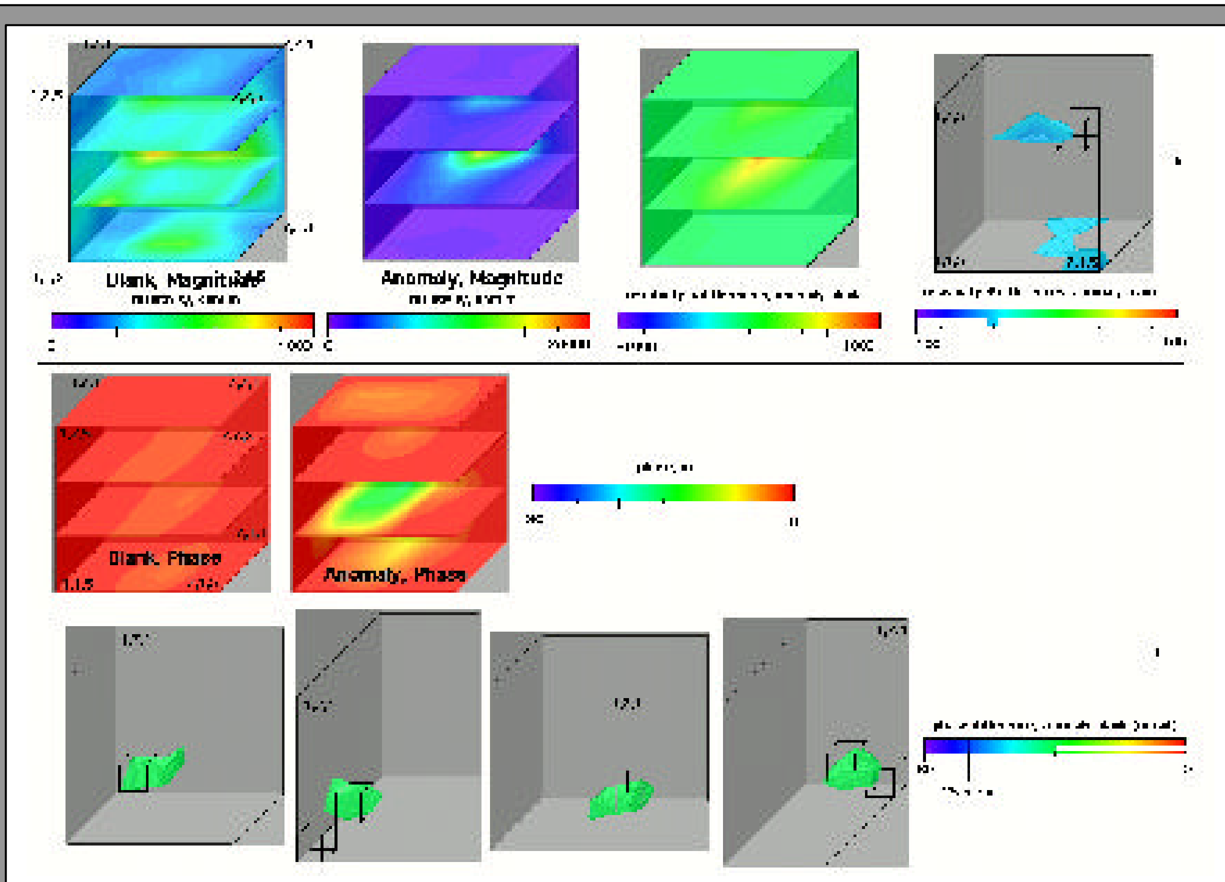
- ORHY-01b - Dense Non-Aqueous Phase Liquids (DNAPLs) Source Characterization, Containment, and Treatment
- ORHY-01 - Dense Non-Aqueous Phase Liquids (DNAPLs) Source Characterization, Containment, and Treatment
- SR99-3017 - Dense Non-Aqueous Phase Liquids (DNAPLs) Characterization and Remediation Technologies
- SR99-3021 - Alternative Sample Collection and Well Installation Technology That Eliminates or Significantly Reduces Aqueous or Non-Aqueous Investigation-Derived Waste (IDW)

TECHNOLOGY BENEFITS

EIT For Subsurface Imaging can reduce the cost and environmental impact of locating the spacial extent of DNAPLs. This technology can be used along with other technologies to satisfy the subsurface site characterization, remediation, and monitoring needs of the U.S. Department of Energy. EIT For Subsurface Imaging can minimize the use of more intrusive and expensive approaches, such as conventional drilling, sampling, and off-site laboratory analysis, for identifying underground contaminants, such as DNAPLs, by locating and mapping contaminated areas in advance. Another benefit is a reduction in IDW. EIT For Subsurface Imaging can provide near real-time results for monitoring remediation processes which can lower operational costs that result from downtime as well as off-site sample analysis that would otherwise be necessary to locate and map the spacial extent of the contaminant plume.



Physical Structure of Network Model of Known Impedance Used as Calibration Standard



Voxel by voxel comparisons (top) are made between the reconstructions of the uniform resistive network and the nonuniform reactive network. Some of the voxels are made transparent so that key internal features can be viewed without being obscured by the outer portions of the image block. Images are also shown (middle) of the percent differences between the magnitudes of the corresponding voxels. Finally, the color bar is adjusted to highlight the differences expected from the known component values. The phase images (bottom) are formed by computing the differences between the phase values of the corresponding voxels.

TECHNOLOGY CAPABILITIES/LIMITATIONS

- Calibration is typically accurate to better than one percent; unfortunately, this calibration is only a lower limit of the errors in field data where electrode noise, cable coupling, external noise sources, etc., will combine to increase the errors and decrease accuracy.
- Errors may vary from one electrode pair to another, or even change with time.
- It is difficult to obtain a reliable measure of accuracy since fitting the forward model calculations to the measured data to an arbitrarily close tolerance can lead to obviously incorrect inversions.
- The actual resistance magnitude errors are dominated by sources other than the data acquisition electronics such as electrode material, formation resistivity, formation electrochemistry, and ambient electromagnetic noise.
- Both electromagnetic magnitude and phase data are necessary for directly mapping contaminant DNAPL plumes *in situ*.

COLLABORATION/TECHNOLOGY TRANSFER

Publications and Presentations

- W. Daily and A. Ramirez (October 1,1996). "Electrical Impedance Tomography of the 1995 Oregon Graduate Institute (OGI) Gasoline Release," Lawrence Livermore National Laboratory, UCRL-ID-125461. 31p.

- W. Daily and A. Ramirez (October 1,1996). "Electrical Impedance Tomography of the 1995 OGI Gasoline Release," Lawrence Livermore National Laboratory, UCRL-ID-125461. 20p.

- Abelardo Ramirez, William Daily, Andrew Binley, and Douglas LaBrecque (March 1998). "Electrical Impedance Tomography of Known Targets," Lawrence Livermore National Laboratory, Lancaster University, and SteamTech, Inc., Unpublished, 20p.

- Ramirez, W. Daily, A. Binley, and D. LaBrecque (December 1, 1998). "Laboratory Scale Tests of Electrical Impedance Tomography," Lawrence Livermore National Laboratory. In Proceedings of Symposium of the Applications of Geophysics to Engineering and Environmental Problems, Oakland, California, March 14-18, 1999. UCRL-JC-132657 Preprint, 11p.

- William Daily and Abe Ramirez (May 2000). "Calibration of Electrical Impedance Tomography," Lawrence Livermore National Laboratory, Unpublished, 8p.

ACCOMPLISHMENTS AND ONGOING WORK

FY 1995 Accomplishments

The experiment at Oregon Graduate Institute for imaging DNAPLs using Electrical Resistance Tomography (ERT) in a controlled release demonstrated that DNAPL could be imaged if changes in distribution could be used by comparing images before and after the change. The DNAPLs could not be imaged using absolute data.

FY 1996 Accomplishments

The experiment conducted at the Hanford site demonstrated that ERT could detect leaks as small as 100 gallons beneath a single shell tank and the resulting plumes could be mapped. The advance of the salt-water plume was followed to a depth of 35 feet.

FY 1997 Accomplishments

At Brookhaven National Laboratory a subsurface barrier imaging experiment-was conducted that demonstrated ERT could map the distribution of viscous liquid barrier materials by comparing before and after emplacement images. In the Dover Air Force Base subsurface barrier imaging experiment it was demonstrated that ERT could be used to map leak points in a thin wall barrier flooded with water by imaging water movement through the leak points.

FY 1998 Accomplishments

Electrical impedance tomography (EIT) was developed for subsurface imaging and an experiment was planned for mapping DNAL using EIT.

FY 1999 Accomplishments

Not funded this fiscal year.

FY 2000 Accomplishments and Ongoing Work

The EIT system was calibrated. Laboratory and computer modeling was used to set limits on the accuracy of the data acquisition system and inversion codes working together.

TECHNICAL TASK PLAN/TECHNOLOGY MANAGEMENT SYSTEM INFORMATION

TTP No./Title: SF24C223 - Electrical Impedance Tomography for Subsurface Imaging
Tech ID/Title: 2121 - Imaging System for Mapping DNAPLs in Soils Using Complex Resistivity Tomography

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